OIPE JC177
OCT 2 7 2004
PATENT & TRADEMARK OFFICE

VERIFICATION OF TRANSLATION

I, Hiroyasu Nakamura, of ISONO INTERNATIONAL PATENT OFFICE, Sabo-kaikan Annex, 7-4, Hirakawa-cho 2-chome, Chiyoda-ku, Tokyo, Japan, am the translator of the documents attached and I state that the following is a true translation to the best of my knowledge and belief.

Signature of translator: Hiroyasu Nakamura
Hiroyasu Nakamura

Date: October 26, 2004

PATENT OFFICE
JAPANESE GOVERNMENT

This is to certify that the annexed is a true copy of the following application as filed with this Office.

Date of Application: December 21, 1999

Application Number: Japanese Patent Application Hei 11-363482

Applicant(s): Honda Giken Kogyo Kabushiki Kaisha

Date: October 6, 2000

Commissioner, Kouzo Oikawa (Sealed)

Patent Office

Reference Number 2000-3082989

Patent Application Hei 11-363485

[Name of Document] Patent Application

[Reference Number] H099940301

[Filing Date] December 21, 1999

[Addressed to] Commissioner of Patent Office

[International Classification] B01D 1/16

[Inventor]

[Domicile] c/o Honda Giken Kogyo Kabushiki Kaisga 4-1, Chuo 1-chome,Wako-shi, Saitama

[Name] Naoyuki Abe

[Inventor]

[Domicile] c/o Honda Giken Kogyo Kabushiki Kaisga 4-1, Chuo 1-chome,Wako-shi, Saitama

[Name] Kiyoshi Kasahara

[Inventor]

[Domicile] c/o Honda Giken Kogyo Kabushiki Kaisga 4-1, Chuo 1-chome,Wako-shi, Saitama

[Name] Takahiro Tachihara

[Inventor]

[Domicile] c/o Honda Giken Kogyo Kabushiki Kaisga 4-1, Chuo 1-chome,Wako-shi, Saitama

[Name] Masahito Nakamura

[Applicant]

[Identification Number] 000005326

[Name] Honda Giken Kogyo Kabushiki Kaisga

[Attorney]

[Identification Number] 100064414

[Patent Attorney]

[Name] Michizo ISONO

[Telephone] 03-5211-2488

[Indication of Official Fee]

[No. of Payment Ledger] 015392

[Amount] 21,000 Yen

[Filing Documents]

[Name of Documents] Specification 1

[Name of Documents] Drawings 1

[Name of Documents] Abstract 1

[No of General Power9713945

of attorney]

[Request for Proof] Yes

[Name of Document] Specification

[Title of the Invention] Fuel Evaporator

[Claims]

[Claim 1]

A fuel evaporator composed of an evaporation chamber which evaporates a raw liquid fuel by a high temperature thermal medium to provide a raw fuel gas, comprising

a chamber for controlling a gas temperature, which is connected to said evaporation chamber and which controls the temperature of the raw fuel gas transferred from said evaporation chamber by means of heat-exchange with said high temperature thermal medium,

a passage for a high temperature thermal medium, which is connected to one end of said evaporation chamber, and which introduces said high temperature thermal medium into said chamber for controlling the gas temperature;

a bypass channel, which is communicated with said passage for the high temperature thermal medium, and which discharge said high temperature thermal medium bypassing said chamber for controlling the gas temperature, and a bypass valve; and

a bypass controller which controls the opening degree of said bypass valve.

[Claim 2]

A fuel evaporator composed of an evaporation chamber which evaporates a raw liquid fuel by a high temperature thermal medium to provide a raw fuel gas, comprising

a chamber for controlling a gas temperature, which is connected to said evaporation chamber and which controls the temperature of the raw fuel gas transferred from said evaporation chamber by means of heat-exchange with said high temperature thermal medium,

a passage for a high temperature thermal medium, which is connected to one end of said evaporation chamber, and which introduces said high temperature thermal medium into said chamber for controlling the gas temperature;

a passage for a low temperature thermal medium, which is connected to said passage for the high temperature thermal medium, and which mixes a low temperature thermal medium having a temperature lower than that of said high temperature thermal medium with said high temperature thermal medium, a low temperature thermal medium inlet and a valve for supplying said low temperature thermal medium; and

a controller which controls the opening degree of said valve for supplying said low temperature thermal medium.

[Detailed Description of the Invention]

[0001]

[Technical Field]

The present invention relates to a fuel evaporator which can be suitably utilized in a fuel cell system in which a raw fuel gas produced by evaporating a raw liquid fuel is reformed in a reformer, and then supplied to a fuel cell to generate electricity.

[0002]

[Prior Art]

A fuel cell system has hitherto been known in which a raw liquid fuel composed of a mixture of methanol with water is injected into a fuel cell evaporator (evaporation chamber) through a raw liquid raw fuel gas injection apparatus to evaporate the raw liquid fuel to thereby produce a raw fuel gas, the resulting raw fuel gas is reformed in a reformer and carbon monoxide contained therein is removed to prepare a raw fuel gas which is a hydrogen enriched gas, and the hydrogen-enriched raw fuel gas is supplied to the fuel cell to generate electricity. Meanwhile, in the case where the fuel cell system constructed as described above is utilized under the conditions that change in the load is extremely large, e.g., in the case of the fuel cell system carried on a fuel cell electric vehicle, if the raw liquid fuel is sharply injected within the fuel evaporator in order to meet the requirement of increasing the operating power, all of the raw liquid fuel cannot be evaporated, sometimes causing residence of the raw liquid fuel (hereinafter referred to as "liquid residence") in the fuel evaporator. Similarly, the liquid residence easily occurs if the fuel evaporator is not sufficiently heated due to the lacking of the heat value used for in evaporation, for example, at the time of starting the fuel cell system.

[0003]

When the liquid residence is generated, the liquid

residence, which sustained within the fuel evaporator, is evaporated even if the injection of the raw liquid fuel is stopped, generating the raw fuel gas. This unduly results in changing the response of the fuel evaporator for the worse. In the case where the raw liquid fuel is made of a mixture, among the resulting liquid residence, the components is evaporated in the order of easiness of the evaporation and, thus, there causes unevenness in the gas compositions of the raw fuel gas. This sometimes causes the situation where the reformer does not exhibit its performance sufficiently or the situation where carbon dioxide cannot be sufficiently removed, decreasing the performance of the fuel cell.

[0004]

In light of such a situation, for the purpose of attaining good response of the fuel evaporator in order to effectively prevent the generation of the liquid residence and, at the same time, for the purpose of quickly warming up the fuel evaporator, our Japanese Patent Application No. 11-125366 (not disclosed) suggests, a fuel evaporator 100, as shown in Fig. 18. This fuel evaporator 100 is composed of a body 110 of the fuel evaporator and a superheating portion 150 residing at the downstream of the body 110 of the fuel evaporator, and a raw fuel injection apparatus 140 provided on the upper portion of the body 10.

Into this fuel evaporator 100, is supplied a combustion gas HG (high temperature thermal medium) obtained by catalytically combusting a hydrogen-containing off gas, which

is generated in the fuel cell (not shown), in a catalytic combustor (not shown) as a heat source. The combustion gas HG enters from an inlet 112_{in}, and is passed through the inside of a plurality of U-shaped tubes 112 for thermal medium (referred to as thermal medium tubes) provided in a evaporation chamber 111 within the body 110 of the fuel evaporator to reach an outlet 112_{out}. Subsequently, the combustion gas HG is passed through a combustion gas passage 113 provided on the lower portion of the body 110 of the fuel evaporator, and introduced into the superheating portion 150 provided downstream of the body 110 of the fuel evaporator. The raw liquid fuel FL composed of a mixture of methanol with water is injected from the raw liquid fuel injector 140 in the state of mist, is heated on the thermal medium tubes 112 and is evaporated to be the raw fuel gas FG. The raw fuel gas FG is passed through the interior of evaporation tube 151 provided within the superheating portion 150 to be superheated and then introduced into a reformer (not shown) residing at the downstream of the superheating portion 150.

[0005]

In this fuel evaporator 100, the lower surface 111b of the evaporation chamber 111 in the body 110 of the fuel evaporator also serves as the upper surface 113t of the combustion gas passage 113. Consequently, since heat is also supplied from the lower surface 111b of the evaporation chamber 111, the generation of the liquid residence is prevented and, even if

the liquid residence occurs, the liquid can be quickly evaporated. Accordingly, the fuel evaporator 110 is of good response. Also, the warming up of the fuel evaporator 110 can be conducted in a quick manner.

[0006]

[Problem to be Solved by the Invention]

However, the combustion gas HG, which is a heat source of the conventional fuel evaporator 100 is changed depending upon the operation conditions of the fuel cell and, thus, it is required that a required amount of the raw liquid fuel FL should be evaporated using heat of combusting hydrogen and then is supplied to the reactor. However, there is a problem that the situations of the evaporation in the evaporation chamber 111 (e.g., generation of liquid residence) and the temperature of the raw fuel gas FG are changed by various factors such as the change in the heating value supplied (change in the operation conditions), heat mass of the fuel evaporator itself, and change in atmospheric temperature.

In the case where the fuel cell system is carried on an fuel cell/electric automobile, it is required for the fuel evaporator that the raw liquid fuel is quickly evaporated at the time of starting the system or of sharply changing the load, i.e., the raw fuel gas is obtained with much better response. Furthermore, it is desired for driving the reformer under good conditions that the raw fuel gas is supplied at an appropriate temperature without unevenness of the temperature. In addition,

if the raw fuel gas having an appropriate temperature range is obtained at the time of heavy load state, the conventional fuel evaporator has a problem that the temperature of the raw fuel gas under middle or low load conditions becomes unduly high.

[0007]

[Means for Solving Problem]

A fuel evaporator composed of an evaporation chamber which evaporates a raw liquid fuel by a high temperature thermal medium to provide a raw fuel gas, comprises a chamber for controlling a gas temperature, which is connected to said evaporation chamber and which controls the temperature of the raw fuel gas transferred from said evaporation chamber by means of heat-exchange with said high temperature thermal medium, a passage for a high temperature thermal medium, which is connected to one end of said evaporation chamber, and which introduces said high temperature thermal medium into said chamber for controlling the gas temperature; a bypass channel, which is communicated with said passage for the high temperature thermal medium, and which discharge said high temperature thermal medium bypassing said chamber for controlling the gas temperature, and a bypass valve; and a bypass controller which controls the opening degree of said bypass valve.

[0008]

According to this configuration, the raw fuel gas obtained (generated) within the evaporation chamber is introduced into

the chamber for controlling a gas temperature at which the temperature of the gas is controlled and unevenness of the temperature is dissolution. The amount of the high temperature thermal medium can be adjusted by the bypass valve. Consequently, when the amount is set to be high, the heat to which the raw fuel gas is acquired can be increased. Conversely, if the amount is set to be small, the heat can be decreased. This makes it possible to ensure the temperature control of the raw fuel gas at the chamber for controlling a gas, and to supply the raw fuel gas in an appropriate amount with an appropriate temperature to the later apparatuses and devices.

[0009]

A fuel evaporator composed of an evaporation chamber which evaporates a raw liquid fuel by a high temperature thermal medium to provide a raw fuel gas, comprising a chamber for controlling a gas temperature, which is connected to said evaporation chamber and which controls the temperature of the raw fuel gas transferred from said evaporation chamber by means of heat-exchange with said high temperature thermal medium, a passage for a high temperature thermal medium, which is connected to one end of said evaporation chamber, and which introduces said high temperature thermal medium into said chamber for controlling the gas temperature; a passage for a low temperature thermal medium, which is connected to said passage for the high temperature thermal medium, and which mixes a low temperature thermal medium having a temperature

lower than that of said high temperature thermal medium with said high temperature thermal medium, a low temperature thermal medium inlet and a valve for supplying said low temperature thermal medium; and a controller which controls the opening degree of said valve for supplying said low temperature thermal medium.

[0010]

According to this configuration, the raw fuel gas obtained (generated) within the evaporation chamber is introduced into the chamber for controlling a gas temperature at which the temperature of the gas is controlled and unevenness of the temperature is dissolution. Here, the low temperature thermal medium may be mixed with the high temperature thermal medium to be introduced into the chamber for controlling a gas. Consequently, the temperature of the high temperature thermal medium can be decreased by mixing with the low temperature thermal medium. By stopping the mixture with the low temperature thermal medium, the temperature of the high temperature thermal medium can be decreased. As described above, by varying the amount of the low temperature thermal medium to be mixed, the temperature of the raw fuel gas can controlled in an ensured manner, making it possible to supply the raw fuel gas in an appropriate amount with an appropriate temperature to the later apparatuses and devices.

[0011]

[Description of Embodiments]

Embodiments of the present invention will now be described by referring to the drawings. The embodiments of the present invention can be divided into two embodiments, i.e., the first embodiment where a high temperature thermal medium to be introduced into a chamber for controlling a gas is bypassed and the second embodiment where a low temperature thermal medium is mixed with the high temperature thermal medium to be introduced into a chamber for controlling a gas.

[0012]

<<First Embodiment>>

The fuel evaporator according to the first embodiment will now be described.

Fig. 1 shows the configuration of a fuel cell system, in which a fuel evaporator according to the first embodiment of the present invention is used. Fig. 2 is a partial cutaway plane view of the fuel evaporator according to the first embodiment of the present invention. Fig. 3 is a cross-sectional view taken along the line A-A of Fig. 2. Fig. 4 is a cross-sectional view taken along the line B-B of Fig. 2.

[0013]

[Fuel Cell System]

First, the configuration of a fuel cell system FCS in which the fuel evaporator 1 of the first embodiment is used will be described by referring to Fig. 1. The fuel cell system FCS is composed mainly of a fuel evaporator 1, a reformer 2, a CO

remover 3, an air compressor 4, a fuel cell 5, a gas/liquid separator 6, a combustion burner 7, and a tank T for a raw liquid fuel (a tank for storing a water/methanol mixed liquid).

[0014]

The fuel evaporator 1 possesses a body 10 of the fuel evaporator, a catalytic combustor 20, a chamber 30 for controlling the temperature of the gas (hereinafter referred to as temperature-control chamber), and a raw liquid fuel injection apparatus 40. The fuel evaporator 1 is an apparatus in which a raw liquid fuel, such as a water/methanol mixed liquid, pumped from the tank T for the raw liquid fuel via a pump P, is injected into the body 10 of the fuel evaporator to be converted into the raw fuel gas. The high temperature thermal medium for evaporating the raw liquid fuel is a combustion gas supplied from the catalytic combustor 20. The combustion gas is obtained by catalytically combusting the off-gas etc. in the fuel cell 5 in the catalytic combustor 20. The raw fuel gas obtained as described above whose temperature is controlled in the temperature-control chamber 30 is supplied into the reformer 2. The details of the fuel evaporator will be described later on.

[0015]

The reformer 2 reforms the raw fuel gas supplied from the fuel evaporator 1 into a hydrogen-enriched raw fuel gas due to steam reforming and partial oxidation. With regard to the steam reforming and partial oxidation, the reactions are accelerated

by the function of a catalyst filled within the reformer 2. In order to partially oxidize the raw fuel gas, air is supplied into the reformer 2 via the air compressor 4 through pipes (not shown).

[0016]

In the resulting hydrogen-enriched raw fuel gas, carbon monoxide is selectively reacted in the presence of a catalyst by means of the CO remover. This converts carbon monoxide into carbon dioxide, which is then removed. The removal of carbon monoxide is carried out in order to prevent the platinum catalyst from being poised to enlarge the service life of the fuel cell 5. The CO remover 3 typically possesses two CO removers, i.e., No. 1 CO remover 3a and No. 2 CO remover 3b, and quickly decreases the concentration of carbon monoxide in the hydrogen enriched raw fuel gas. The temperature of the hydrogen-enriched raw fuel gas in the CO remover is controlled by means of a heat exchanger not so as to bring about any undesirable reaction such as converse shifting or methanation.

[0017]

The air compressor 4 compresses an air to supply the air required in the fuel cell 5 into the fuel cell 5. The air compressor 4 also supplies the air for partial oxidation in the reformer 2 as described above. Furthermore, the air compressor 4 supplies the air to the No. 2 CO remover 3b in order to convert carbon monoxide contained in the raw fuel gas into carbon dioxide. As the power for the air compressor 4, an energy

generated during the course of swelling the off gas discharged from the fuel cell 5 can be utilized.

[0018]

The fuel cell 5 is a solid macromolecular type fuel cell as described above. Into a hydrogen pole is supplied the raw fuel gas, from which carbon monoxide is removed, and into an oxygen pole of the fuel cell 5 is supplied the air from the air compressor 4. Within the fuel cell 5, water and electricity electrochemically occur from hydrogen and oxygen in the presence of the platinum catalyst. The electricity can be used as a power source for an electric vehicle or such.

[0019]

The off gas containing unused hydrogen and the produced water are discharged from the hydrogen pole of the fuel cell 5, and they are separated into gaseous components and liquid components by means of a gas/liquid separator 6. At the time of starting the fuel cell system FCS, the off gas is supplied into a combustion burner 7 and then combusted to warm up the catalytic combustor 20 etc. After the completion of the warming-up, the off gas is supplied into the fuel evaporator 1 without combustion in the combustion burner 7, and is catalytically combusted in the catalytic combustor 20 to be used as a heat source for the evaporation of the raw liquid fuel. At the time of starting the fuel cell system FCS, a fuel for catalytic combustion (e.g., methanol) is supplied into the catalytic combustor 20 instead of the off gas.

The functions and configuration of the fuel cell system FCS in which the fuel evaporator 1 according to the first embodiment is used are described above.

[0020]

[0020]

[Fuel evaporator]

The fuel evaporator 1 according to this embodiment will now be described [see Figs. 2-4]. The fuel evaporator 1 according to the first embodiment comprises a body 10 of the fuel evaporator which evaporates a raw liquid fuel FL to generate a raw fuel gas FG, a catalytic combustor 20 which generates a combustion gas HG serving as a high temperature thermal medium, a chamber 30 for controlling the temperature of the raw fuel gas, and a raw fuel gas injection apparatus 40 which injects the raw liquid fuel FL.

With regard to the schematic positions of them, the body 10 of the fuel evaporator is placed on the upper portion of the catalytic combustor 20, the temperature control chamber 30 is placed on one side of the body 10 of the fuel evaporator, and the raw liquid fuel injection apparatus 40 is placed on the upper portion of the body 10 of the fuel evaporator.

The fuel evaporator 1 according to the first embodiment possesses a bypass channel 51, which withdraws the combustion gas (high temperature thermal medium) introduced into the temperature control chamber 30 and bypasses it without passing through the temperature control chamber 30, a bypass valve BV,

and a controller FIC for controlling the opening degree of the bypass valve V.

[0021]

(1) Body of Fuel Evaporator

As shown in Fig. 3 or such, the body 10 of the fuel evaporator possesses a boxy evaporation chamber 11 having a plurality of U-shaped tubes 12 for thermal medium. The evaporation chamber 11 evaporates the raw liquid fuel FL injected from the raw liquid fuel injection apparatus 40 by means of the combustion gas HG, which serves as the high temperature thermal medium, to bring about the raw fuel gas FG.

[0022]

As shown in Fig. 3, the thermal medium tubes 12 in the evaporation chamber 11 are placed so that the distances between the respective thermal medium tubes 12 become wider toward the upper direction and they become narrower toward the lower direction (i.e., the thermal medium tubes become denser as they are further from the injector 41), in order to widespread the raw liquid fuel FL injected from the injector 41 among every portions of the evaporation chamber 11 including the portion far from the injector 41. Also, by such a configuration, the generation of big film boiling such as the film boiling spread between the thermal medium tubes 12 can be reduced (i.e., the distances between the thermal medium tubes 12 at the portion near the injector 41 are widened to prevent greatly grow in the portions where the film boiling occurs), to thereby secure the

passages of the raw liquid fuel FL and the raw fuel gas FG. By placing the thermal medium tubes 12 at the lower portion of the evaporation chamber 11 in a dense manner, and by strongly heating the lower portion of the evaporation chamber 11, the liquid residence on the lower portion of the first evaporator chamber 11 can also be prevented (the generation of the liquid residence on the lower portion of the evaporation chamber 11 is also prevented by increasing the heat mass at the lower portion of the evaporation chamber 11).

[0023]

As shown in Fig. 3, the cross-section of the lower surface 11 of the evaporation chamber 11 is configured into a wave form to meet the shape (placements) of the thermal medium tubes 12 residing at the lower portion amongst them, so as to minimize the space between the thermal medium tubes 12 and the lower portion of the evaporation chamber as low as possible not so as to generate any large liquid residence. However, there are some gaps between the lower surface 11b of the evaporation chamber 11 and the thermal medium tubes 12 for residing at the lower portion not so as to come in contact with each other due to the vibration etc.

[0024]

As shown in Fig. 4, the front side of the evaporation chamber 11 (on the basis of the fuel evaporator 1) is blocked with a supporting plate 12a to hold the thermal medium tubes 12 not so as to mix the combustion gas HG with the raw fuel gas

FG. Both ends of the thermal medium tube 12 are opened, and the combustion gas HG enters into the thermal medium tube 12 from the lower end of the thermal medium tube 12 (inlet 12_{in} of the thermal medium tube), while existing from the upper end of the thermal medium tube 12 (outlet 12_{out} of the thermal medium tube). From the outlet 12_{out} of the thermal medium tube, a combustion gas passage 13, which will be described later on, is started. Here, with regard to the positions such as front, side, and rear sides, they are based on the fuel evaporator 1 (and so forth).

[0025]

The upper side of the thermal medium tube 12 is slanted as described above so as to descend towards the end thereof. The reason why the thermal medium tube 12 has a slant is that in the case where the raw liquid fuel FL is adhered on the upper side of the thermal medium tube 12A in the form of droplets, the droplets thus adhered allow for moving towards the supporting plate 12a to thereby evaporate the droplets due to the heat possessed by the supporting plate 12a.

[0026]

The upper side of the thermal medium tube 12 is slanted so as to descend towards the end thereof. The reason why the thermal medium tube 12 has a slant is that in the case where the raw liquid fuel FL is adhered on the upper side of the thermal medium tube 12 in the form of droplets, the droplets thus adhered allows for moving towards the supporting plate 12a

to thereby evaporate the droplets due to the heat possessed by the supporting plate 12a.

While the body 10 of the fuel evaporator evaporates the raw liquid fuel FL within the evaporation chamber 11 to generate the raw fuel gas FG, the generated raw fuel gas FG is passed through a ventilation means 14 possessed by the outlet of the evaporation chamber 11 to be introduced into the temperature control chamber 30 (see Fig. 3). The ventilation means 14 is composed of a punched plate having many small pores etc. so that the droplets of the raw liquid fuel FL such as fly droplets do not directly enter in the temperature control chamber 30.

[0027]

The fuel evaporator 1 according to the first embodiment possesses a combustion gas passage 13 also severing as keeping the evaporation chamber 11 warm. The combustion gas passage 13 is started at the tube outlet 12_{out} of the evaporation chamber 11 and the front surface, the side surfaces and the rear surface of the evaporation chamber to reach the temperature control chamber 30 (shell inlet 32_{in}. The combustion gas passage 13 has a configuration where t totally covers a diaphragm 24 of the catalytic combustor 20 and a side surface 20s of the catalytic combustor 20.

[0028]

The member represented by the symbol 15 in Fig. 2 is an air inlet, which introduces air (oxygen) required for the reformation (partial oxidation) into the reformer 2 at the

stage of generating the raw fuel gas FG in the fuel evaporator 1 in order to mix the air with the raw fuel gas FG. By mixing the air with the raw fuel gas FG, the reaction in the reformer 2 takes place smoothly. This function is the same as that of the first embodiment.

[0029]

(2) Catalytic Combustor

The catalytic combustor 20 according to the first embodiment of the present invention is in a box form similar to the case of the evaporation chamber 11, and has a catalytic layer 22 comprising a catalyst in the shape of a honeycomb accommodated therewith. The catalytic combustor 20 combusts the off gas OG from the fuel cell 5, which is the gas to be combusted, i.e., a mixed gas comprising hydrogen and oxygen. The combusted gas HG generated due to the catalytic combustion of the off gas OG is used as a high temperature thermal medium in the evaporation of the raw liquid fuel FL in the evaporation chamber, keeping the temperature of the evaporation chamber 11 warm, and controlling the temperature of the temperature control chamber 30.

[0030]

Due to catalytic combustion in the interior thereof, the catalytic combustor 20 itself is kept at a high temperature. In this embodiment, since the catalytic combustor 20 itself makes a use of the heat generated, the catalytic combustor 20 is placed so that the upper surface thereof (the upper surface

20t of the catalytic combustor) is in contact with the lower surface 11b of the evaporation chamber 11. By such a contact, the heat generated in the catalytic combustor 20 is transmitted to the lower surface 11b of the evaporation chamber in a thermal conductive manner, making it possible to effectively use the heat generated in the catalytic combustor 20.

[0031]

The lower surface 11b of the evaporation chamber is a place in which the liquid residence is generated. Accordingly, strong heating of the lower surface 11b of the evaporation chamber by manes of the catalytic combustor 20 can prevent the generation of the liquid residence and can be intended to rapidly evaporate the liquid residence, if it occurs. Such a configuration can be intended to effectively utilize the exhaust heat. It may be configured that the upper surface 20t of the catalytic combustor also severs as the lower surface 11b of the evaporation chamber 11; that an electric heater is intervened between the upper surface 20t of the catalytic combustor and the lower surface 11b of the evaporation chamber 11; or that the upper surface 20t of the catalytic combustor and the lower surface 11b of the evaporation chamber 11 are placed at a several distance so that the heat generated in the catalytic combustor 20 is transmitted to the evaporation chamber 11 due to the radiation and the convection of the generated heat.

[0032]

With the catalytic combustor 20 is equipped a diaphragm 24 having a semicircular cross-section, which introduce the raw fuel gas HG from the exit 23 of the catalytic combustor into the tube inlet 12_{in} in the evaporation chamber 11. This diaphragm 23 forbids the combustion gas HF at the exist 23 of the catalytic combustor (tube inlet 12_{in}) and the combustion gas HG at the tube outlet 12_{out} to be mixed with each other. With regard to the materials for the catalytic combustor 20 and the catalytic layer (honeycomb material), stainless steel (e.g., SUS316), which withstands a high temperature and which has corrosion resistance, is suitable.

[0033]

(3) Temperature control chamber

The temperature control chamber 30 is placed at the downstream of the exit of the evaporation chamber 11, projecting from one side of the body 10 of the fuel evaporator. As shown in Fig. 3, the temperature control chamber 30 is a shell and tube type heat exchanger. The raw fuel gas flows in at the side of the thermal medium tubes of the temperature control chamber 30 (the raw fuel gas FG is introduced into the tube 31 from a tube inlet 31_{in}, and discharged from a tube outlet 31_{out}). The combustion gas HG flows in at the side of the shell 32 (the combustion gas HG is introduced in the shell 32 from the shell inlet 32_{in} and discharged from the shell outlet 32_{out}). The temperature control chamber 30 dissociates the temperature unevenness of the raw fuel gas FG generated in the evaporation

chamber 11. At the same time, the temperature control chamber 30 also plays a role in superheating the raw fuel gas FG, which will be condensed, to dry vapor, preventing the raw fuel gas FG from being condensed. In this embodiment, the combustion gas HG, which has heated the evaporation chamber 11, is introduced into the temperature control chamber 30. The temperature control camber 30 according to the first embodiment also has a similar configuration as that of the temperature control chamber 30 in the fuel evaporation 1 according to the first embodiment.

[0034]

(4) Bypass:

The bypass channel 51 is a bypass channel for the combustion gas HG, which is breached at the shell inlet 32_{in} of the temperature control chamber 30, bypasses the shell 32, and is jointed to the shell outlet 32_{out} (See Figs. 2 and 5). The bypass valve BV in the first embodiment is a butterfly valve actuated by a stepping motor. A controller FIC for controlling the injection of the raw liquid fuel, which will be described later on, serves as the bypass controller, and controls the opening degree of the bypass valve BV.

By such a configuration, the amount of the combustion gas HG supplied to the temperature control chamber 30 is varied to thereby control the temperature of the raw fuel gas FG.

After the flow direction of the combustion gas is turned 90° (after the flow of the combustion gas HG becomes parallel

to the flow of the combustion gas HG flowing through the thermal medium tube 12), the combustion gas HG straightly enters in the shell inlet 32_{in} and flows within the shell 32. The bypass channel 51 is connected to the combustion gas passage in such a manner that the combustion gas HG passing through the combustion gas passage 13 flows straightly.

[0035]

(5) Raw fuel gas injector

The raw fuel gas injection apparatus 40 is an injection apparatus having a single fluid nozzle and injects the raw fuel gas FG into the evaporation chamber 11. The raw fuel gas injection apparatus 40 comprises injectors 41 for injecting the raw fuel gas FL and a tube 42 for supplying the raw liquid fuel FL, and is provided on the upper surface 11t of the evaporation chamber. In this embodiment, three injectors 41 (41_1, 41_2, and 41_3) are provided on the evaporation chamber 11. In order to effectively utilize the thermal capacity possessed by the high temperature combustion gas HG, the raw liquid fuel FL is mainly injected to the direction along the plurality of the thermal medium tubes 12 provided within the evaporation chamber 11 (the direction toward the supporting plate 12a of the thermal medium tubes 12).

[0036]

The raw liquid fuel FL injected from the injector $41_1$is directionally injected so as to mainly evaporate the raw liquid fuel FL at the left side of the evaporation chamber 11, the raw

liquid fuel FL injected from the injector $41_2$is directionally injected so as to mainly evaporate the raw liquid fuel FL at the center of the evaporation chamber 11, and the raw liquid fuel FL injected from the injector $41_3$is directionally injected so as to mainly evaporate the raw liquid fuel FL at the right side of the evaporation chamber 11 (see Fig. 2). Specifically, the portion where no raw liquid fuel FL is injected is in so-called empty heating.

[0037]

(6) Thermo sensor/Controller for injecting raw liquid fuel

By referring to Figs. 2 to 5, a thermo sensor, which measures the temperature within the fuel evaporator and a controller for injecting the raw liquid fuel, which actuates receiving the temperature signals from the thermo sensor, etc., will now be described.

A thermo sensor Tg_{in} is provided at the outlet 21 of the catalytic combustor; a thermo sensor Tg_1 is provided at the outlet portion of the thermal medium tube 12A at the front of the evaporation chamber 11 (the initiation portion of the combustion gas channel3); and a thermo sensor Tg_0 is provided at the shell inlet 32_{in} of the temperature control chamber 30, and these thermo sensors detect the temperatures of the combustion gas HG at the portions where they are provided. The detected temperature signals are transferred to a controller FIC for injecting the raw liquid fuel.

[0038]

A thermo sensor Tv_1 is provided at the outlet of the evaporation chamber 11 (the tube inlet 31_{in} of the temperature control chamber 30); and a thermo sensor Tv_2 is provided at the tube outlet 31_{out} of the temperature control chamber 30, and these thermo sensors detect the temperatures of the combustion gas HG at the portions where they are provided. The detected temperature signals are transferred to the controller FIC for injecting the raw liquid fuel.

[0039]

The controller FIC for injecting the raw liquid fuel, which receives the temperature signals etc., has an injection amount controller which controls the amount of raw liquid fuel FL injected from the raw liquid fuel injection apparatus 40 and a selector which selects at least one injector to be used (actuated) among the three injectors 41_1, 41_2, and 41_2.

[0040]

(General Operation of fuel evaporator)

Next, the operation and functions of the fuel evaporator 1 according to the first embodiment will be described.

(1) Heating of lower surface of fuel evaporator

Into the catalytic combustor 20, the off gas OG from the fuel cell 5 is supplied, which is catalytically combusted to produce the combustion gas HG. Once the catalytic combustion is initiated, the temperature of the catalytic combustor 20 itself is also increased, and the external surface of the catalytic combustor 20 becomes high (about 300°C). Here, the

fuel evaporator 1 has the lower surface 11b of the fuel evaporation chamber 11 coming into contact with the upper surface 20t of the catalytic combustor. Consequently, the lower surface 11b of the evaporation chamber 11 (bed surface of the evaporation chamber 11) is heated to a high temperature by means of the catalytic combustor 20. As described above, by effectively utilizing the heat generated from the catalytic combustor 20, the generation of the liquid residence can be prevented, and the liquid residence, even if it occurs, can be rapidly evaporated.

[0041]

(2) Flow of combustion gas

The symbols (P1) to (p7), utilized herein, indicate the flows of the combustion gas HG according to the symbols P1 to P7 described in Figs. 1 to 4.

First, the combustion gas HG (P1) having a high temperature at from 650 to 700°C, produced by catalytically combusting the off gas by means of the catalytic combustor 20 enters from the tube inlet 12_{in} into the thermal medium tube 12, heats the evaporation chamber 11, and exits the thermal medium tube 12 from the tube outlet $12A_{out}$ (P2). At this time, the combustion gas HG transmits and evaporates the heat to the raw liquid fuel FL coming into contact with the thermal medium tube 12. The temperature of the combustion gas HG at the tube outlet $12A_{out}$ is approximately 350°C.

[0042]

Next, the combustion gas HG enters in the first combustion passage 13, is passed through the front surface (P3) of the evaporation chamber 11, the side surface (P4) of the evaporation chamber 11 including the side surface 20s of the catalytic combustor, the rear surface (P5) of the evaporation chamber 11, and reaches the shell inlet 32_{in} (P6) of the temperature control chamber 30. During this course, the combustion gas HG mainly serves as keeping the temperature of the evaporation chamber 11 warm. The temperature of the combustion gas HG at the shell inlet 32_{in} (P6) of the temperature control chamber 30 is approximately 300°C.

[0043]

The combustion gas HG after being passed through the shell 32 of the temperature control chamber 30 is discharged from an exhaust duct (P7). During this course, the combustion gas HG controls the temperature of the raw fuel gas FG.

[0044]

In the case where part of the combustion gas HG is bypassed through the temperature control chamber, the part of the combustion gas HG is branched from the combustion gas passage 13 by means of the bypass valve BV to enter in the bypass channel (P8). The combustion gas HG entering in the bypass channel is then jointed to the combustion gas HG having being passed through the shell 32 of the temperature control chamber 30 at the downstream of the temperature control chamber 30 (See Fig. 5).

[0045]

As described above, by passing the combustion gas HG through the interior of the fuel evaporator 1, the evaporation of the raw liquid fuel FL is further accelerated, which allows for the fuel evaporator excelling in good response. This also allows for raid warming up. Furthermore, the amount of the combustion gas bypassed is adjusted to control the heat value imparted to the raw fuel gas HG, whereby the temperature of the raw fuel gas FG is positively controlled.

[0046]

(3) Flows of fuel liquid and raw fuel gas:

The raw liquid fuel FL stored in a raw liquid fuel tank T (storage tank for water/methanol mixture) is pumped and injected into the evaporation chamber 11 by means of the injectors 41 (41_1, 41_2, and 41_3) of the raw liquid fuel injection apparatus 40. In the first embodiment, there provided three injectors 41 of raw liquid fuel injection apparatus 40 on the evaporation chamber 11, so that the raw liquid fuel can be injected from a desired injector 41x to the target evaporation chamber 11. By using a specific injector(s) 41 selected among the injectors, the temperature of the raw fuel gas FG can be controlled. The details will be described later on in the column of "Specific control of the raw liquid fuel injector".

[0047]

The raw liquid fuel, injected from the injector(s) 40 of the raw liquid fuel injection apparatus 40 into the evaporation

chamber 40, is rapidly evaporated to be the raw fuel gas FG. In the case where the raw liquid fuel FL is injected sharply in a large amount, with regard to the raw liquid fuel FG remaining un-evaporated, (1) due to heat-exchange with the evaporated raw fuel gas, the temperature of the remaining raw liquid fuel FG is increased during the course of being dropped to the lower portion of the evaporation chamber 11 (part of the remaining raw liquid fuel is evaporated); (2) if the remaining raw liquid fuel FL is dropped on the thermal medium tube 12 residing at the lower portion, it is evaporated due to the heat on the surface of the thermal medium tube 12; and (3) the raw liquid fuel finally remaining unevaporated, which reaches the lower surface 11b of the evaporation chamber, is evaporated without bringing about the liquid residence, because the lower surface 11b of the evaporation chamber is heated by the catalytic combustor 20 or such to a high temperature.

Also, (4) since the body 10 of the fuel evaporator (evaporation chamber 11) is heated and kept warm by the combustion gas passage 13, the evaporation of the raw liquid fuel FL is further accelerated, making it difficult to bring about the liquid residence.

[0048]

Specifically, in such a type of the conventional fuel evaporator, respective surfaces of the evaporation chamber are only heated by the evaporated raw fuel gas and/or the heat conducted or transferred from thermal medium tubes.

Consequently, in the conventional fuel evaporator, the raw liquid fuel FL adhered on the side surface is difficult to be evaporated and has a tendency to be condensed (i.e., tendency to generate the liquid residence.)

In contrast, according to the fuel evaporator 1 of this embodiment, which has a configuration that a plurality of the surfaces of the evaporation chamber 11 are heated and kept warm by means of the combustion gas HG and the catalytic combustor 20, the generation of the liquid residence can be rapidly prevented (i.e., the fuel evaporator 1 of this embodiment has good response).

[0049]

Also, since the thermal medium tubes 12 are placed so that sparser the distances between respective thermal medium tubes 12 are nearer the injectors 41_1, 41_2 and 41_3, the fuel evaporator 1 according to this embodiment can evaporate the raw liquid fuel FL in a good manner. At the same time, according to the fuel evaporator of this embodiment, it is difficult to bring about the film boiling, which has a possibility to inhibit the flowing of the raw liquid fuel FL and the fuel gad FG, at any portions near the injectors 41_1, 41_2 and 41_3 and, thus, the fuel evaporator 1 can effectively evaporate the raw liquid fuel FL in a good manner.

[0050]

The raw fuel gas FG evaporated at the evaporation chamber 11 is passed through the ventilation means 14 such as

perforation plate having many small pores, enters in the temperature control chamber 30, is passed through a vapor tube 31 to control the temperature thereof, and then is introduced into the reformer 2 as shown in Fig. 1. By passing the raw fuel gas FG through the temperature control chamber 30 as just mentioned, the uneven temperature of the raw fuel gas FG can be solved.

[0051]

[Specific Control of the raw liquid fuel injector]

Next, specific descriptions will be described for the control of the fuel evaporator according to the first embodiment, particularly for the control of the temperature of the raw liquid fuel at the outlet of the evaporation chamber (the outlet of the fuel evaporator) by switching the position where the raw liquid fuel is injected. The fuel evaporator described herein is accommodated within the fuel cell system and is carried on a vehicle (an electric vehicle carrying a fuel cell).

Fig. 6 is a drawing showing the relation between the position of injecting the raw liquid fuel in an evaporation chamber and the gas temperature at the outlet of the evaporation chamber. Fig. 7(a) is a drawing which explains an aimed temperature range and a tolerance temperature range of the raw fuel gas, and Fig. 7(b) shows a basic injection pattern at a stationary state. Fig. 8 is a flowchart showing the control of the fuel evaporator according to the first embodiment of the

present invention at a stationary state. Fig. 9 is a flowchart showing the control of the fuel evaporator according to the first embodiment of the present invention at an accelerated state. Fig. 10 is a drawing showing the relation between the operation power and the temperature of the raw fuel gas in the fuel cell system using the fuel evaporator according to the first embodiment of the present invention.

[0052]

(1) Relation between the position of the raw liquid fuel injector and the temperature of the raw fuel gas:

We have separately made a test for how to inject the raw liquid fuel in order to obtain a raw fuel gas having a temperature within the preferable range. Specifically, utilizing an evaporation chamber (like the first evaporation chamber 11A) having three injectors, which are means for injecting the raw liquid fuel, each differing in the distance from the outlet of the evaporation chamber, the temperature of the raw fuel gas was measured for each injector, when the same amount of the raw liquid fuel was injected. This made the relation between the injection position of the raw liquid fuel and the temperature of the raw fuel gas at the outlet of the evaporation chamber clear.

[0053]

As shown in Fig. 6, the temperature of the raw fuel gas became the highest when the raw fuel gas was injected from the injector A, positioned at the innermost of the evaporation

chamber both at the time of idling and under a low load. Also, the temperature of the raw fuel gas became the lowest when the raw fuel gas was injected from the injector C, positioned at the portion nearest the evaporation chamber both at the time of idling and under a low load (the same injection amount). Furthermore, the temperature of the raw fuel gas was between the temperatures of the raw fuel gas injected from the injectors A and C, when the raw fuel gas was injected from the injector B, positioned at the center of the evaporation chamber both at the time of idling and under a low load (the same injection amount).

[0054]

From these results, it can be understood that in the fuel evaporator 1 according to first embodiment, the temperature of the raw fuel gas at the outlet of the evaporation chamber can be increased by selecting the positions of the injector for injecting the raw fuel gas to inject the raw fuel gas from the injector positioned at the innermost of the evaporation chamber. On the other hand, it is also proven that the temperature of the raw fuel gas at the outlet of the evaporation chamber can be decreased by injecting the raw fuel gas from the injector positioned at the portion nearest the evaporation chamber. By dealing with the change in the amount of the heat value applied to the raw liquid fuel or the raw fuel gas according to the change of the position to be injected, the following temperature control is carried out in this embodiment.

[0055]

(2) Temperature control of raw fuel gas depending upon position where raw fuel gas is injected (stationary state):

First, the temperature control of raw fuel gas at the outlet of the evaporation chamber depending upon position where raw fuel gas is injected will be described by referring to Figs. 7 and 8.

Fig. 7(a) is a drawing which explains an operation power of the fuel cell and an aimed temperature range of the raw fuel gas. In this figure, Tv_{max} is the upper limit of the tolerance temperature range and Tv_{min} is the lower limit of the tolerance temperature range. Also, in this figure, Tv_{high} is the upper limit of the aimed temperature range, and Tv_{low} is the lower limit of the aimed temperature range. By keeping the temperature of the raw fuel gas FG within this aimed temperature range, FCS can be driven under good conditions.

[0056]

Fig. 7(b) shows a basic injection pattern of the injector. This basic injection pattern shows the injection pattern of the raw fuel gas at a stationary state (different from the first embodiment, the number of the injector is three in this embodiment).

Specifically, (1) at the time of idling (idle) where the operation power of the fuel cell is the lowest, only a small amount of the raw fuel gas FG is required. Consequently, the raw liquid fuel FL is injected from the injector 41_2, positioned

at the side near the outlet of the evaporation chamber 11.

(2) In the situation where the operation power of the fuel cell 5 is somewhat higher than that at the time of idling, the amount of the raw fuel gas FG is required to be somewhat increased to increase a heat value. Consequently, in this case, the raw liquid fuel FL is also injected from the injector 41_2, positioned at the middle of the evaporation chamber 11.

(3) In the situation where the operation power of the fuel cell 5 is further higher, the amount of the raw fuel gas FG is further increased to apply a larger heat value. Consequently, the injection of the raw liquid fuel FL from the injector 41_2 is stopped, and alternatively the raw liquid fuel FL is injected from injector 41_1, which can generate the raw fuel gas FG at the highest temperature and which is posited at the innermost of the evaporation chamber 11. In this case, although the number of the injectors 41 which inject the raw liquid fuel is the same as that in the case of situation (2), i.e., two injectors, the injection amount of the raw liquid fuel FL in the case of (3) is larger than that in the case of (2), by setting a pulse control signal which controls the period of opening and closing the injectors 41.

(4) In the situation of wide-opening the throttle (WOT), the operation power of the fuel cell 5 becomes highest. In this case, the raw liquid fuel FL is injected from all of three injectors 41_1, 41_2, and 41_3 of the evaporation chamber 11.

[0057]

By injecting the raw liquid fuel FL into the evaporation chamber 11 in the manner as described above, the raw fuel gas FG can be generated at the optimal temperature in an adequate amount in any situations from at the time of idling through at the time of wide-opening the throttle (stationary state).

[0058]

By referring to the flowchart shown in Fig. 8, the temperature control of the raw fuel gas depending upon the position of injecting the raw liquid fuel will now be described (stationary state). This flowchart assumes the case of carrying the fuel cell system FCS on a vehicle.

The symbols Tv_1 and Tv_2 used in the following description do not mean the temperature sensors for the raw fuel gas but mean the temperatures of the raw fuel gas detected by the temperature sensors. Similarly, the symbols Tg_{in}, Tg_1, and Tg_0 also do not mean the temperature sensors but means the temperatures of the raw fuel gas detected by the temperature sensors.

[0059]

First, the controller judges whether or not the fuel evaporator is warming up (S1). If the fuel evaporator is warming up, warming up is carried out through a warming up subroutine (S17). Subsequently, the controller judges whether or not there is a change in the opening degree of the throttle ($\Delta\theta th$) (S2). If the change in the opening degree of the throttle ($\Delta\theta th$) exists, the acceleration is carried out by acceleration

subroutine (S18). The acceleration subroutine carries out the injection of raw liquid fuel FL during the course of the acceleration (during the transition).

[0060]

If the controller judges that no change in opening degree of the throttle ($\Delta\theta th$) exists in S02, injectors 41 are selected based on the basic injection pattern (see Fig. 7(b)), by referring to the speed of the vehicle, the opening degree of the throttle (θth) and the like (S3). A Ti-Q map is read, and the injection time Ti of raw liquid fuel FL (injection amount Q of the raw liquid fuel) is temporarily assumed (S4). Then, the correction based on various correction terms such as charge into the battery, actuations of accessories, etc., and the injection time Ti of the raw liquid fuel is determined by calculation (S5). Based on the basic injection pattern selected in Step S3 and the injection time Ti determined in Step S5, the fuel is injected from the injectors 41 (S6).

For example, in the case where the throttle (θth) is somewhat opened, the injector 41_3 and the injector 41_2 are selected (S3), the injection time Ti is then calculated (S4 and S5) and the like, the injector 41_3 and the injector 41_2 are controlled to actuate for the calculated period (S6).

[0061]

Subsequently, the temperature Tv_2 of the raw fuel gas at the tube outlet 31_{out} of the temperature control chamber 30 is compared with the upper limit Tv_{high} of the aimed temperature

range shown in Fig. 8(a) (S7). If the temperature Tv_2 of the raw fuel gas is higher, the temperature of the raw fuel gas FL is treated to be decreased. Specifically, the temperature inclines of the temperatures Tv_1 and Tv_2 of the raw fuel gas at the measuring points are calculated (S8). Also, the temperature inclines of the temperatures Tg_{in}, Tg_1, and Tg_0 of the combustion gas (temperature inclines between Tg_{in} and Tg_1; Tg_1 and Tg_0) at the respective measuring points are calculated (S9). Based on these temperature inclines, prescribed ΔTv-injection pattern table is read (S10). Subsequently, the positions of the injectors 41 are switched on the basis of the ΔTv-injection pattern table.

Specifically, for example, in the case where the raw liquid fuel FL is injected from the injectors $41A_1$, $41A_2$, and $41A_3$, if Tv_2 becomes higher than Tv_{high} ($Tv_2 > Tv_{high}$), the ΔTv-injection pattern table is given so as to switch the injection from the injector $41A_1$ to the injection from the injector 41_3.

With series of treatments, the temperature (Tv_2) of the raw fuel gas is decreased to fall within the aimed temperature range.

[0062]

On the other hand, if Step S7 judges that the temperature (Tv_2) of the raw fuel gas is lower than the upper limit Tv_{high} of the aimed temperature range, the temperature (Tv_2) of the raw fuel gas is compared with the lower limit Tv_{min} of the aimed

temperature range (S2). If the temperature (Tv_2) of the raw fuel gas is higher than the lower limit Tv_{min} of the aimed temperature range, the temperature (Tv_2) of the raw fuel gas is within the optimal range, being returned to the initial step. Conversely, if the temperature (Tv_2) of the raw fuel gas is lower than the lower limit Tv_{min} of the aimed temperature range, the temperature (Tv_2) of the raw fuel gas should be increased. Specifically, the temperature incline of the temperatures Tv_1, and Tv_2 of the raw fuel gas at the respective measuring points is calculated (S13). Also, the temperature inclines of the temperatures Tg_{in}, Tg_1, , and Tg_0 of the combustion gas (temperature inclines between Tg_{in} and Tg_1; Tg_1 and Tg_0) at the measuring points are calculated (S14). Based on these temperature inclines, prescribed ΔTv-injection pattern table is read (S15). Subsequently, the positions of the injectors 41 are switched on the basis of the ΔTv-injection pattern table.

Specifically, for example, in the case where the raw liquid fuel FL is injected from the injectors 41_3, if Tv_2 becomes lower than Tv_{low} ($Tv_2 < Tv_{low}$), the ΔTv-injection pattern table is given so as to switch the injection from the injector 41_3 to the injection from the injector 41_1.

With series of treatments, the temperature (Tv_2) of the raw fuel gas is increased to fall within the aimed temperature range.

[0063]

With these treatments, the temperature of the raw fuel gas

FG, particularly under the stationary states, can fall within the adequate temperature range, irrelevant to the amount of generating the raw fuel gas FG (operation power of the fuel cell 5).

[0064]

(3) Securing of the amount of generating raw fuel gas at the time of acceleration:

By referring to the flowchart shown in Fig. 9, the control for securing the amount of generating raw fuel gas at the time of acceleration (during the transition) will now be described. This flowchart also assumes the case in which the fuel cell system FCS is carried on the vehicle.

First, the controller judges whether or not there is a change in the opening degree of the throttle ($\Delta\theta th$) (S21). If the controller judges that no change in opening degree of the throttle ($\Delta\theta th$) exists, the stationary drive routine is carried out (S38, see Fig. 8). If the change in the opening degree of the throttle ($\Delta\theta th$) exists, the controller judges whether or not the amount of the change in the opening degree of the throttle ($\Delta\theta th$) is larger than the predetermined amount (S22). In the case where amount of the change in the opening degree of the throttle ($\Delta\theta th$) is larger than the predetermined amount ($\Delta\theta th > k$), i.e., at the time of acceleration by middle-opening the throttle or wide-opening the throttle, the controller judges whether or not respective injectors 41 are stopped (S23).

[0065]

With regard to the injector 41 or the injectors 41, which is/are actuated, the injection time Ti of the raw liquid fuel FL is calculated from the respective correction terms (S24), an injector increase map 2 is read to determine the injection amount (injection time) (S25), and the injection amount from the corresponding injector 41 is increased.

On the other hand, with regard to the injector 41 or the injectors 41, which is/are stopped, the injection time Ti of the raw liquid fuel FL is calculated from the respective correction terms (S27), an injector increase map 3 is read to determine the injection amount (injection time) (S28), the injector 41 or the injectors 41, which is/are not actuated, is/are actuated to inject the raw liquid fuel FL (S29).

This makes it possible to deal with the requirement for increasing the amount of the raw fuel gas FG at the transition time of acceleration by middle-opening the throttle or wide opening the throttle.

[0066]

In Step S22, in the case where the change in the opening degree of the throttle ($\Delta\theta th$) is not more than the predetermined level ($\Delta\theta th <= k$), i.e., when the requirement of the vehicle for the acceleration is weak, the controller judges whether or not the injector(s) 41 is/are actuated (make(s) an injection) (S33). An injector 41 which is not injecting the raw liquid fuel FL, remains stopping, and an injector 41, which is now

injecting the raw liquid fuel FL, is used to meet the requirement. Specifically, the injector 41 which is not injecting the raw liquid fuel FL, remains stopping (S37).

With regard to the actuating injector(s) 41, the injection time Ti is calculated on the basis of the respective correction terms (S34), the liquid FL is injected on the basis of a map 1 for increasing the injection amount from the injector (S35), to deal with the requirement increasing the raw fuel gas FG for the slight acceleration.

[0067]

As described above, by starting the actuation of the stopped injector 41, and increasing the amount of the raw liquid fuel FL injected from the actuating injector(s), the requirement for increasing the amount of the raw fuel gas FG in the slight acceleration can be dealt. Specifically, at the time of the acceleration, the heat value to meet the injection amount of the raw liquid fuel is not immediately supplied to the evaporation chamber in the conventional manner, but the time-lag occurs in the supply of the heat value as a rule, resulting in the situation where the conventional fuel evaporator cannot be dealt with the requirement for increasing the amount of the raw fuel gas. In contrast, as in the case of this embodiment, by injecting the raw liquid fuel FL to the portions which does not directly contribute to the evaporation of the raw liquid fuel FL (so-called empty heated evaporation chamber 11 [such as the thermal medium tube 12]), due to the

heat value (thermal mass) possessed by such portions like the thermal medium tube 12, the requirement increasing the amount of the raw fuel gas can be readily reposed.

[0068]

(4) Control by Bypass

The temperature control by bypassing the combustion gas through the temperature control chamber 30 will now be described (at the stationary) (See Fig. 7).

Fig. 10 is a flowchart showing the control where the temperature of the raw fuel gas is controlled by bypassing the combustion gas of the fuel evaporator. This flowchart assumes the case of carrying the fuel cell system FCS on a vehicle.

[0069]

First, the controller judges whether or not the fuel evaporator is warming up (S51). If the fuel evaporator is warming up, warming up is carried out through a warming up subroutine (S64). Subsequently, the controller judges whether or not there is a change in the opening degree of the throttle ($\Delta\theta th$). If the change in the opening degree of the throttle ($\Delta\theta th$) exists, the acceleration is carried out by acceleration subroutine (S65). The acceleration subroutine carries out the injection of raw liquid fuel FL during the course of the acceleration (during the transition).

[0070]

If the controller judges that no change in opening degree of the throttle ($\Delta\theta th$) exists in Step S52, injectors 41 are

selected based on the basic injection pattern (see Fig. 7(b)), by referring to the speed of the vehicle, the opening degree of the throttle (θth) and the like (S53). A Ti-Q map is read, and the injection time Ti of raw liquid fuel FL (injection amount Q of the raw liquid fuel) is temporarily assumed (S54). Then, the correction based on various correction terms such as charge into the battery, actuations of accessories, etc., and the injection time Ti of the raw liquid fuel is determined by calculation (S55). Based on the basic injection pattern selected in Step S53 and the injection time Ti determined in Step S55, the fuel is injected from the injectors 41 (S56).

For example, in the case where the throttle (θth) is somewhat opened, the injector 41_2 and the injector $41A_3$ are selected, the injection time Ti is then calculated, and the injector 41_2 and the injector $41A_3$ are controlled to actuate for the calculated period.

[0071]

Subsequently, the temperature Tv_2 of the raw fuel gas at the tube outlet 31_{out} of the temperature control chamber 30 is compared with the upper limit Tv_{high} of the aimed temperature range shown in Fig. 7(a) (S57). If the temperature Tv_2 of the raw fuel gas is higher, the temperature of the raw fuel gas FL is treated to be decreased. Specifically, the temperature incline of the temperatures Tv_1, and Tv_2 of the raw fuel gas at the respective measuring points is calculated (S58). Also, the temperature inclines of the temperatures Tg_{in}, Tg_1, and Tg_0

of the combustion gas (temperature inclines between Tg_{in} and Tg_1; Tg_2 and Tg_0) at the respective measuring points are calculated (S59). Furthermore, the temperature Tg_0 of the combustion gas is detected and the calculation of the correction terms is carried out (S60). Based on the calculation, a STEP-Q map of the bypass valve BV is read and calculated to determine the opening degree (STEP) of the bypass valve BV (S61). Then, based on the determined opening degree, the bypass valve BV is turned on (S62). By the series of the operations, the amount of the combustion gas HG flowing at the side of the shell 30 in the temperature control chamber 30 is suppressed, whereby the heat value imparted to the raw fuel gas FG is decreased, and the temperature (Tv_2) of the raw fuel gas FG is decreased to be within the aimed temperature range.

[0072]

On the other hand, in Step 57, if the temperature (Tv_2) of the raw fuel gas FG is judged to be lower than the upper limit Tv_{high} of the aimed temperature range, the bypass valve BV is turned off to wide-open the valve (S63). This treatment suppresses the heat loss.

[0073]

As described above, when the combustion gas serving as the heat source is withdrawn and bypasses the temperature control chamber, the temperature control of the raw fuel gas and the control of the amount of the raw fuel gas generated can be accurately carried out. Also, by selectively injecting the raw

liquid fuel from three injectors within the evaporation chamber, the temperature and the amount of the raw fuel gas generated can be accurately controlled in much more suitable manner. Consequently, the fuel evaporator according to this embodiment having good response can be utilized as the fuel evaporator used under the condition where extremely large variation in the load.

[0074]

Fig. 11 is a drawing showing the relation between the operation power and the temperature of the raw fuel gas in the fuel cell system using the fuel evaporator according to the first embodiment of the present invention.

The conventional fuel evaporator has been designated so that the temperature of the raw fuel gas (the temperature of the raw fuel gas at the outlet of the apparatus) falls within the suitable range when the operation power of the fuel cell is largely loaded. Consequently, in the case where a relatively low load is applied, which is at a low operation power, or where a middle load is applied, which is a middle operation power, there is a problem in that the temperature of the raw fuel gas (the temperature of the raw fuel gas at the outlet of the apparatus) becomes higher than the upper limit of the suitable temperature range.

However, according to the first embodiment of the present invention, a significant effect that the temperature of the raw fuel gas (the temperature of the raw fuel gas at the outlet of

the apparatus) can fall within the suitable range over the entire load level of the operation power from a low load to a high load.

[0075]

<<Second Embodiment>>

Next, the fuel evaporator according to the second embodiment of the present invention will now be described. The fuel evaporator according to the first embodiment allows for positive temperature control of the raw fuel gas by mixing with the combustion gas which is introduced into the temperature control chamber, air (diluted air) as a thermal medium having a temperature lower than this combustion gas.

With regard to the same members and elements as in those utilized in the first embodiment, descriptions will be made by referring to the drawings utilized in the first embodiments, or are omitted.

Fig. 12 is a partial cutaway plane view of the fuel evaporator according to the second embodiment of the present invention. Fig. 13 is a block diagram showing the control system of the fuel evaporator according to the second embodiment of the present invention.

[0076]

[Fuel cell system]

The fuel cell system according to the second embodiment is the same as that according to the first embodiment, and the description thereof will be omitted.

[0077]

[Fuel evaporator]

The fuel evaporator according to the second embodiment has all of the configurations possessed by the fuel evaporator according to the first embodiment, except for the configuration for bypassing the combustion gas (bypass valve, bypass channel, bypass controller). In addition, the fuel evaporator according to the second embodiment possesses an inlet for diluted air (inlet for low temperature thermal medium), which mixes diluted air with the combustion gas to be introduced into the temperature control chamber, a diluted air passage (low temperature thermal medium passage), a valve for supplying the diluted air (valve for supplying the low temperature thermal medium), and a controller for the valve for supplying the diluted air (valve for supplying the low temperature thermal medium), which controls the opening degree of the valve for supplying the diluted air.

[0078]

The air compressor 4 shown in Fig. 1 serves as the inlet for the diluted air. More specifically, the diluted air is the air supplied from the compressor 4. A diluted air supply passage 51 is a piping, which connects the air compressor 4 with the shell inlet 32_{in} of the temperature control chamber 30, and a raw fuel injection apparatus 40. The temperature of the diluted air is approximately from 10 to 70°C.

[0079]

A diluted air supply valve ACV according to the second embodiment is a butterfly valve actuated by a stepping motor. The controller FIC for injecting the raw liquid fuel serves as a controller for the valve for supplying the diluted air to control the diluted air supply valve ACV. In Fig. 12, the symbol 62 stands for a check valve, and the symbol T_{air} represents a thermo sensor which detects the temperature of the diluted air.

Utilizing such a configuration as described above, the temperature of the combustion gas HG supplied into the temperature control chamber 30 is varied whereby the temperature of the raw fuel gas FG is controlled.

[0080]

(General actuation of the fuel evaporator)

Among general control processes of the fuel evaporator 1 according to the second embodiment, the control (at stationary state) of the temperature of the raw fuel gas FG by mixing the diluted air with the combustion gas HG inherent to this embodiment will now be described. In the following description, the symbol T_{air} does not represent a thermo sensor which detects the temperature of the diluted air, but represents the temperature of the diluted air detected by this thermo sensor.

Fig. 14 is a flowchart showing the control where the temperature of the raw fuel gas is controlled by mixing a diluted air with the combustion gas of the fuel evaporator according to the second embodiment of the present invention. This flowchart assumes the case in which the fuel cell system

FCS is carried on the vehicle.

[0082]

First, the controller judges whether or not the fuel evaporator is warming up (S71). If the fuel evaporator is warming up, warming up is carried out through a warming up subroutine (S84). Subsequently, the controller judges whether or not there is a change in the opening degree of the throttle ($\Delta\theta th$) (S72). If the change in the opening degree of the throttle ($\Delta\theta th$) exists, the acceleration is carried out by acceleration subroutine (S75). The acceleration subroutine carries out the injection of raw liquid fuel FL during the course of the acceleration (during the transition).

[0083]

If the controller judges in Step 72 that no change in opening degree of the throttle ($\Delta\theta th$) exists, injectors 41 are selected based on the basic injection pattern (see Fig. 7(b)), by referring to the speed of the vehicle, the opening degree of the throttle (θth) (S73). A Ti-Q map is read, and the injection time Ti of raw liquid fuel FL (injection amount Q of the raw liquid fuel) is temporarily assumed (S74). Then, the correction based on various correction terms such as charge into the battery, actuations of accessories, etc., and the injection time Ti of the raw liquid fuel is determined by calculation (S75). Based on the basic injection pattern selected in Step S73 and the injection time Ti determined in Step S75, the fuel is injected from the injectors 41 (S76).

For example, in the case where the throttle (θth) is somewhat opened, the injector $41A_3$ and the injector $41A_2$ are selected, the injection time Ti is then calculated, the injector 41_2 and the injector $41A_3$ are controlled to actuate for the calculated period.

[0084]

Subsequently, the temperature Tv_2 of the raw fuel gas at the tube outlet 31_{out} of the temperature control chamber 30 is compared with the upper limit Tv_{high} of the aimed temperature range shown in Fig. 7(a) (S77). If the temperature Tv_2 of the raw fuel gas is higher, the temperature of the raw fuel gas FL is treated to be decreased. Specifically, the temperature incline of the temperatures Tv_1, and Tv_2 of the raw fuel gas at the respective measuring points is calculated (S78). Also, the temperature inclines of the temperatures Tg_{in}, Tg_1, and Tg_0 of the combustion gas (temperature inclines between Tg_{in} and Tg_1; Tg_2 and Tg_0) at the respective measuring points are calculated (S79). Furthermore, the controller detects the pressure P_{air} and the temperature T_{air} of the diluted air and, carries out the calculation of the correction terms (S80). Based on the calculation, STEP-Q map of the diluted air supply valve ACV is read and calculated to determine the opening degree (STEP) of the diluted air supply valve ACV (S71). Then, based on the determined opening degree, the diluted air supply valve ACV is turned on (S82). By the series of the operations, an adequate amount of the diluted air is supplied to the shell side

32 of the temperature control chamber 30 (to mix the combustion gas HG with the diluted air), whereby the temperature (Tv_2) of the raw fuel gas FG flowing in the side of the shell 32 is decreased to be within the aimed temperature range.

[0085]

On the other hand, in Step 77, if the temperature (Tv_2) of the raw fuel gas FG is judged to be lower than the upper limit Tv_{high} of the aimed temperature range, the diluted air supply valve ACV is turned off to wide-open the valve (S83). This treatment suppresses the heat loss.

[0086]

As described above, when the diluted air is mixed with the combustion gas to be supplied into the temperature control chamber 30, the temperature of the raw fuel gas can be controlled similar to that of the first embodiment.

[0087]

While the embodiments of the fuel evaporators according to the present invention have been described, the fuel evaporator according to the fourth embodiment is not restricted to these embodiments, and various modifications can be made.

For example, the combustion gas passages which are passages for the high temperature thermal medium may be provided on the upper surface of the evaporation chamber. By such a configuration, the escape of the heat from the upper surface of the evaporation chamber can be prevented. The catalytic combustor may be replaced by a combustion burner or

an electric heater. As the high temperature thermal medium, the combustion gas whose heat is exchanged with air or a liquid, an air or a liquid heated by an electric heater may also be used. Also, the number of the injectors may be two or four or more.

[0088]

For example, in the case where the heat value of the combustion gas is excess, part of the combustion gas is bypassed at the outlet of the catalytic combustor to be discharged. Conversely, in the case where the heat value of the combustion gas is lacking, auxiliary fuel such as methanol is electrically heated to be evaporated, and the evaporated auxiliary fuel is combusted in the catalytic combustor to increase the heat value of the combustion gas. The fuel cell is not restricted to a macromolecular type and may be a phosphoric acid type fuel cell (PAFC). Also, this embodiment may be performed irrelevant to the shape of the evaporation chamber. Moreover, various embodiments may be combined. Also, the fuel evaporator having the configuration in combination of the first embodiments with the second embodiment may be put into practical use.

[0089]

[Effect of Invention]

According to the present invention (Claim 1), the raw fuel gas obtained (generated) within the evaporation chamber is introduced into the chamber for controlling a gas temperature at which the temperature of the gas is controlled and unevenness of the temperature is dissolution. The amount of the high

temperature thermal medium can be adjusted by the bypass valve. Consequently, when the amount is set to be high, the heat to which the raw fuel gas is acquired can be increased. Conversely, if the amount is set to be small, the heat can be decreased. This makes it possible to ensure the temperature control of the raw fuel gas at the chamber for controlling a gas, and to supply the raw fuel gas in an appropriate amount with an appropriate temperature to the later apparatuses and devices.

According to the present invention (Claim 2), the raw fuel gas obtained (generated) within the evaporation chamber is introduced into the chamber for controlling a gas temperature at which the temperature of the gas is controlled and unevenness of the temperature is dissolution. Here, the low temperature thermal medium may be mixed with the high temperature thermal medium to be introduced into the chamber for controlling a gas. Consequently, the temperature of the high temperature thermal medium can be decreased by mixing with the low temperature thermal medium. By stopping the mixture with the low temperature thermal medium, the temperature of the high temperature thermal medium can be decreased. As described above, by varying the amount of the low temperature thermal medium to be mixed, the temperature of the raw fuel gas can controlled in an ensured manner, making it possible to supply the raw fuel gas in an appropriate amount with an appropriate temperature to the later apparatuses and devices.

[Brief Description of the Drawings]

Fig. 1 shows the configuration of a fuel cell system, in which a fuel evaporator according to the first embodiment of the present invention is used.

Fig. 2 is a partial cutaway plane view of the fuel evaporator according to the first embodiment of the present invention.

Fig. 3 is a cross-sectional view taken along the line A-A of Fig. 2

Fig. 4 is a cross-sectional view taken along the line B-B of Fig. 2.

Fig. 5 is a block diagram showing the control system of the fuel evaporator according to the first embodiment of the present invention.

Fig. 6 is a drawing showing the relation between the position of injection of the raw liquid fuel in an evaporation chamber and the temperature of the raw fuel gas at the outlet of the evaporation chamber.

Fig. 7(a) is a drawing explaining an aimed temperature range and a tolerance temperature range of the raw fuel gas, and Fig. 7(b) shows a basic injection pattern at a stationary state.

Fig. 8 is a flowchart showing the control of the fuel evaporator according to the first embodiment of the present invention at a stationary state.

Fig. 9 is a flowchart showing the control of the fuel evaporator according to the first embodiment of the present invention

invention at an accelerated state.

Fig. 10 is a flowchart showing the control where the temperature of the raw fuel gas is controlled by bypassing the combustion gas of the fuel evaporator according to the first embodiment of the present invention.

Fig. 11 is a drawing showing the relation between the operation power and the temperature of the raw fuel gas in the fuel cell system using the fuel evaporator according to the first embodiment of the present invention.

Fig. 12 is a partial cutaway plane view of the fuel evaporator according to the second embodiment of the present invention.

Fig. 13 is a block diagram showing the control system of the fuel evaporator according to the second embodiment of the present invention.

Fig. 14 is a flowchart showing the control where the temperature of the raw fuel gas is controlled by mixing a diluted air with the combustion gas of the fuel evaporator according to the second embodiment of the present invention.

Fig. 15 is a cross-sectional view showing the conventional fuel evaporator.

[Description of Symbols]

FL Raw Liquid Fuel

FG Raw Fuel Gas

HG Combustion Gas (High Temperature Thermo Medium)

11 Evaporation Chamber

11A 1st Evaporation Chamber

11B 2nd Evaporation Chamber

11C 3rd Evaporation Chamber

30 Temperature-Control Chamber

40 Raw Liquid Fuel Injection Apparatus

51 Low Temperature Thermo Medium Passage
(Diluted Air Supply Passage)

61 Bypass Passage

FIC Controller for Injecting Raw Liquid Fuel

ACV Low Temperature Thermo Medium Supply Valve
(Diluted Air Supply Valve)

BV Bypass Valve

Tv_1, Tv_2, Tv_3, Tv_4... Thermo Sensor

Tg_{in}, Tg_1, Tg_2, Tg_0... Thermo Sensor

[Abstract]

[Problem]

A fuel evaporator, which can secure sufficient response to a sharp change in the load, which can supply a raw fuel gas at an appropriate temperature into the later reformer is provided.

[Means for Solving Problem]

A fuel evaporator composed of an evaporation chamber 11 which evaporates a raw liquid fuel FL by a high temperature thermal medium HG to provide a raw fuel gas FL, comprises

a chamber 30 for controlling a gas temperature, which controls the temperature of the raw fuel gas FG transferred from the evaporation chamber 11 by means of heat-exchange with the high temperature thermal medium HG; a passage 51 for a high temperature thermal medium HG , which introduces the high temperature thermal medium HG into the chamber 30 for controlling the gas temperature; a bypass channel 51, which discharge the high temperature thermal medium HG bypassing the chamber 30 for controlling the gas temperature, and a bypass valve; and a bypass controller which controls the opening degree of said bypass valve.

[Selected Drawing] Fig. 2